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Polarized structure functions in a constituent quark scenario †

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Abstract

Using a simple picture of the constituent quark as a composite system of point-like partons, we construct the polarized parton distributions by a convolution between constituent quark momentum distributions and constituent quark structure functions. Using unpolarized data to fix the parameters we achieve good agreement with the polarization experiments for the proton, while not so for the neutron. By relaxing our assumptions for the sea distributions, we define new quark functions for the polarized case, which reproduce well the proton data and are in better agreement with the neutron data.

When our results are compared with similar calculations using non-composite constituent quarks the accord with the experiments of the present scheme is impressive. We conclude that, also in the polarized case, DIS data are consistent with a low energy scenario dominated by composite constituents of the nucleon.

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1 Introduction

At low energies, the idea that baryons are made up of three constituent quarks and mesons of a (constituent) quark-antiquark pair [1], the so called naive quark model, accounts for a large number of experimental observations [2]. Soon after the formulation of the naive quark model, deep inelastic scattering of leptons off protons was explained in terms of pointlike constituents named partons [3]. The birth of QCD [4] and the proof that it is asymptotically free [5] set the framework for an understanding of the deep inelastic scattering phenomena beyond the Parton Model [6]. However, the perturbative approach to QCD does not provide absolute values for the observables. The description based on the Operator Product Expansion (OPE) and the QCD evolution requires the input of non-perturbative matrix elements. We have developed an approach which uses model calculations for the non-perturbative matrix elements [7]. Moreover, in order to relate the constituent quark with the current partons of the theory a procedure, hereafter called ACMP, has been applied [8, 9].

In our approach [9] constituent quarks are effective particles made up of point-like partons (current quarks (antiquarks) and gluons), interacting by a residual interaction described as in a quark model. The hadron structure functions are obtained by a convolution of the constituent quark model wave function with the constituent quark structure function.

The procedure has been recently used to estimate the pion structure function [10] and the unpolarized proton one with success [9]. We have shown that DIS data are consistent with a low energy scenario dominated by composite, mainly non-relativistic constituents of the nucleon. In here we extend our analysis to the polarized g_1 structure function.

Summarizing: In section 2 we will review briefly the formalism for the unpolarized case to set the ground for the discussion and present the generalization for the polarized one. Section 3 will contain the comparison with the data of the calculated structure functions. Finally, Section 4 will contain the conclusions and outlook.

2 The theoretical framework

In our picture the constituent quarks are themselves complex objects whose structure functions are described by a set of functions Φ_{ab} that specify the number of point-like partons of type b , which are present in the constituents of type a with fraction x of its total momentum [8, 9]. In general a and b specify all the relevant quantum numbers of the partons, i.e., flavor and spin. The unpolarized case for the proton was discussed in detail in ref.[9]. We proceed to a short review of the description in order to set the ground for the study of the polarized structure function g_1 .

The functions describing the nucleon parton distributions omitting spin degrees of freedom are expressed in terms of the independent $\Phi_{ab}(x)$ and of the constituent probability

distributions u_0 and d_0 , at the hadronic scale μ_0^2 [7], as

$$f(x, \mu_0^2) = \int_x^1 \frac{dz}{z} [u_0(z, \mu_0^2) \Phi_{uf}(\frac{x}{z}, \mu_0^2) + d_0(z, \mu_0^2) \Phi_{df}(\frac{x}{z}, \mu_0^2)] \quad (1)$$

where f labels the various partons, i.e., valence quarks (u_v, d_v), sea quarks (u_s, d_s, s), sea antiquarks ($\bar{u}, \bar{d}, \bar{s}$) and gluons g .

The different types and functional forms of the structure functions for the constituent quarks are derived from three very natural assumptions, extensively discussed and theoretically motivated [8]. Although these ideas were proposed before QCD was fully developed, they can be easily transported to it and result in:

- i) The point-like partons are determined by QCD , therefore, quarks, antiquarks and gluons;
- ii) Regge behavior for $x \rightarrow 0$ and duality ideas;
- iii) invariance under charge conjugation and isospin.

These considerations define in the case of the valence quarks the following structure function [8]

$$\Phi_{qq_v}(x, \mu_0^2) = \frac{\Gamma(A + \frac{1}{2})}{\Gamma(\frac{1}{2})\Gamma(A)} \frac{(1-x)^{A-1}}{\sqrt{x}}. \quad (2)$$

For the sea quarks the corresponding structure function becomes

$$\Phi_{qq_s}(x, \mu_0^2) = \frac{C}{x} (1-x)^{D-1}, \quad (3)$$

and in the case of the gluons we take

$$\Phi_{gg}(x, \mu_0^2) = \frac{G}{x} (1-x)^{B-1}. \quad (4)$$

The other ingredients of the formalism, i.e., the probability distributions for each constituent quark, are defined according to the procedure of Traini et al. [7], that is, a constituent quark, q_0 , has a probability distribution determined by

$$q_0(z, \mu_0^2) = \frac{1}{(1-x)^2} \int d^3k n_q(|\vec{k}|) \delta\left(\frac{z}{1-z} - \frac{k^+}{M}\right), \quad (5)$$

where $n_q(|\vec{k}|)$ is the momentum density distribution for the constituent quark momentum \vec{k} in the corresponding baryonic state and can be calculated as

$$n_{u/d} = \langle N | \sum_{i=1}^3 \delta(\vec{k} - \vec{k}_i) \frac{1 \pm \tau_i^z}{2} | N \rangle. \quad (6)$$

Eq.(5) includes support correction and satisfies the particle number sum rule [7].

Our last assumption relates to the hadronic scale μ_0^2 , i.e., that at which the constituent quark structure is defined. We choose μ_0^2 , as defined in Ref. [7], namely by fixing the momentum carried by the various partons. This hypothesis determines *all the parameters of the approach (Eqs. (2) through (4)), except one*. In fact, the constants A , B , G and the ratio C/D are determined by the amount of momentum carried by the different partons, i.e. by the 2^{nd} moments of the parton distributions. These quantities are experimentally known at high Q^2 . We recover their values at the low μ_0^2 scale by performing a NLO backward evolution in the DIS scheme.

The experience accumulated during the last years [7] suggests the use of a hadronic scale, $\mu_0^2 = 0.34 \text{ GeV}^2$. At this value of the momentum transfer perturbative QCD at NLO tells us that 53.5 % of the nucleon momentum is carried by the valence quarks, 35.7 % by the gluons and the rest by the sea. This choice of the hadronic scale fixes the parameters A , B , G and the ratio C/D . Using besides some phenomenological input, the following parameters have been obtained: $A = 0.435$, $B = 0.378$, $C = 0.05$, $D = 2.778$ and $G = 0.135$ [9]. We stress for later purposes that the unpolarized structure function F_2 is rather insensitive to the change of the sea (C , D) and the gluon (B , G) constants.

To complete the process [11, 12, 13] the above input distributions are NLO-evolved in the DIS scheme to 10 GeV^2 , where they are compared with the data.

We next generalize our previous discussion to the polarized case. The functions Φ_{ab} now specify spin and flavor. We next construct the polarized parton distributions with particular emphasis on spin. Let

$$\Delta q(x, \mu_0^2) = q_+(x, \mu_0^2) - q_-(x, \mu_0^2) \quad (7)$$

where \pm label the quark spin projections and q represents any flavor. The generalized *ACMP* approach implies

$$q_i(x, \mu_0^2) = \int_x^1 \frac{dz}{z} \sum_j (u_{0j}(z, \mu_0^2) \Phi_{u_j q_i}(\frac{x}{z}, \mu_0^2) + d_{0j}(z, \mu_0^2) \Phi_{d_j q_i}(\frac{x}{z}, \mu_0^2)) \quad (8)$$

where $i = \pm$ labels the partonic spin projections and $j = \pm$ the constituent quark spins. Using spin symmetry we arrive at ¹

$$\Delta q(x) = \int_x^1 \frac{dz}{z} (\Delta u_0(z) \Delta \Phi_{uq}(\frac{x}{z}) + \Delta d_0(z) \Delta \Phi_{dq}(\frac{x}{z})) \quad (9)$$

where $\Delta q_0 = q_{0+} - q_{0-}$, and

$$\Delta \Phi_{uq} = \Phi_{u+q+} - \Phi_{u+q-} \quad (10)$$

$$\Delta \Phi_{dq} = \Phi_{d+q+} - \Phi_{d+q-} \quad (11)$$

Note at this point that the unpolarized case can be described in this generalized formalism as

¹We omit writing explicitly the hadronic scale dependence from now on, unless needed for clarity.

$$q(x) = q_+(x) + q_-(x) = \int_x^1 \frac{dz}{z} (u_0(z) \Phi_{uq}(\frac{x}{z}) + d_0(z) \Phi_{dq}(\frac{x}{z})), \quad (12)$$

where

$$\Phi_{uq} = \Phi_{u+q+} + \Phi_{u+q-}, \quad (13)$$

$$\Phi_{dq} = \Phi_{d+q+} + \Phi_{d+q-}. \quad (14)$$

We next reformulate the description in term of the conventional valence and sea quark separation, i.e.,

$$\begin{aligned} \Delta q(x) &= \Delta q_v(x) + \Delta q_s(x) = \\ &= \int_x^1 \frac{dz}{z} (\Delta u_0(z) (\Delta \Phi_{uq_v}(\frac{x}{z}) + \Delta \Phi_{uq_s}(\frac{x}{z})) + \Delta d_0(z) (\Delta \Phi_{dq_v}(\frac{x}{z}) + \Delta \Phi_{dq_s}(\frac{x}{z}))) \end{aligned} \quad (15)$$

Here $\Delta \Phi_{qq_v} = \Delta \Phi_{qq_v} \delta_{qq}$, therefore

$$\Delta q_v(x) = \int_x^1 \frac{dz}{z} \Delta q_0(z) \Delta \Phi_{qq_v}(\frac{x}{z}), \quad (16)$$

$$\Delta q_s(x) = \int_x^1 \frac{dz}{z} (\Delta u_0(z) \Delta \Phi_{uq_s}(\frac{x}{z}) + \Delta d_0(z) \Delta \Phi_{dq_s}(\frac{x}{z})). \quad (17)$$

We introduce $SU(6)$ (spin-isospin) symmetry as a simplifying assumption, which leads to

$$\Delta \Phi_{uu} = \Delta \Phi_{dd} \quad (18)$$

and

$$\Delta \Phi_{ud} = \Delta \Phi_{du}. \quad (19)$$

Furthermore they imply

$$\Delta \Phi_{uu_v} + \Delta \Phi_{uu_s} = \Delta \Phi_{dd_v} + \Delta \Phi_{dd_s} \quad (20)$$

and

$$\Delta \Phi_{ud_s} = \Delta \Phi_{du_s}. \quad (21)$$

If we now add to these the following relations

$$\Delta \Phi_{uu_s} = \Delta \Phi_{du_s}, \quad (22)$$

$$\Delta \Phi_{dd_s} = \Delta \Phi_{ud_s}, \quad (23)$$

which are beyond $SU(6)$ symmetry, but quite reasonable, we obtain the following equalities

$$\Delta\Phi_{uu_s} = \Delta\Phi_{du_s} = \Delta\Phi_{ud_s} = \Delta\Phi_{dd_s} = \Delta\Phi_{qq_s} \quad (24)$$

and

$$\Delta\Phi_{uu_v} = \Delta\Phi_{dd_v} = \Delta\Phi_{qq_v}. \quad (25)$$

In this way we reduce the structure functions for the valence and for the sea to just two independent constituent structure functions and Eq. (17) simplifies to

$$\Delta q_s(x) = \int_x^1 \frac{dz}{z} (\Delta u_0(z) + \Delta d_0(z)) \Delta\Phi_{qq_s}\left(\frac{x}{z}\right). \quad (26)$$

The same argumentation applied to gluons implies

$$\Delta g(x) = \int_x^1 \frac{dz}{z} (\Delta u_0(z) + \Delta d_0(z)) \Delta\Phi_{gg}\left(\frac{x}{z}\right) \quad (27)$$

and we recover our old expression

$$g(x) = \int_x^1 \frac{dz}{z} (u_0(z) + d_0(z)) \Phi_{gg}\left(\frac{x}{z}\right). \quad (28)$$

We may conclude our analysis up to now by stating that the *ACMP* procedure can be extended to the polarized case just by introducing three additional structure functions for the constituent quarks: $\Delta\Phi_{qq_v}$, $\Delta\Phi_{qq_s}$ and $\Delta\Phi_{gg}$.

In order to determine the polarized constituent structure functions we add some assumptions which will tie up the constituent structure functions for the polarized and unpolarized cases completely, reducing dramatically the number of parameters. They are:

- iv) factorization assumption: $\Delta\Phi$ cannot depend upon the quark model used, i.e, cannot depend upon the particular Δq_0 ;
- v) positivity assumption: the positivity constraint $\Delta\Phi \leq \Phi$ is saturated for $x = 1$.

We next discuss how these additional assumptions determine completely the parameters of the polarized constituent structure functions and discuss the physics implied by them.

The *QCD* partonic picture, Regge behavior and duality imply that

$$\Delta\Phi_{qf} = \frac{\Delta C_f (1-x)^{A_f-1}}{x^{a_f}} \quad (29)$$

and $-\frac{1}{2} < a_f < 0$, for all $f = q_v, q_s, g$, as defined by dominant exchange of the A_1 meson trajectory [14].

The positivity restriction, $\Delta\Phi \leq \Phi$, is a natural consequence of the probability interpretation of the parton distributions. The assumption that the inequality is saturated for $x = 1$, in the spirit of ref. [15], implies that $\Delta C_f = C_f$, the latter being the parameter

fixed in the analysis of the unpolarized case, and therefore when $x \approx 1$ the partons which carry all of the momentum also carry all of the polarization, i.e., $\Phi_{+-} = 0$. From the point of view of the number of parameters, this is a minimalistic assumption, since it reduces the parameters of the polarized case to those of the unpolarized one. Lastly the exponents A_f are also taken from the unpolarized case. To summarize the parametrization, let us stress that the change between the polarized functions and the unpolarized ones comes only from Regge behavior.

Let us insert here a comment about the constituent quark structure functions. Under the conditions imposed by the generalized *ACMP*, namely that the low x regime is governed by the Regge behavior, and the large x behavior is determined by assuming soft partons to be independently emitted [8], the Φ functions are of the form

$$\Phi_{q+q\pm}(x) = \sum_i \frac{C_{i\pm}}{x^{a_i}} (1-x)^{A-1}, \quad (30)$$

where i sums over leading trajectories. That Regge behavior works reasonably well at *scales typical of soft hadronic physics* has been recently confirmed [16]. For valence quarks, for example, the sum is limited to the rho meson ($a_1 = \frac{1}{2}$) and the A_1 -meson ($-\frac{1}{2} \leq a_2 \leq 0$). The unpolarized structure function is given then by

$$\Phi_{qq_v} = \left(\frac{C_{1+} + C_{1-}}{x^{a_1}} + \frac{C_{2+} + C_{2-}}{x^{a_2}} \right) (1-x)^{(A-1)} \quad (31)$$

and the polarized one by

$$\Delta\Phi_{qq_v} = \left(\frac{C_{1+} - C_{1-}}{x^{a_1}} + \frac{C_{2+} - C_{2-}}{x^{a_2}} \right) (1-x)^{(A-1)}. \quad (32)$$

The observed Regge behavior implies

$$C_{1+} = C_{1-} \quad , \quad C_{2+} = -C_{2-} \quad , \quad (33)$$

and therefore the shapes used above arise. Moreover our additional assumption for the large x limit [15] leads to

$$C_{1+} = C_{2+} \quad . \quad (34)$$

Similar arguments hold for the sea and the gluons.

With all the above hypothesis our constituent quark functions become

$$\Delta\Phi_{qq_v}(x, \mu_0^2) = \frac{\Gamma(A + \frac{1}{2})}{\Gamma(\frac{1}{2})\Gamma(A)} x^\alpha (1-x)^{A-1} \quad (35)$$

$$\Delta\Phi_{qq_s}(x, \mu_0^2) = C x^\alpha (1-x)^{D-1} \quad (36)$$

$$\Delta\Phi_{qg}(x, \mu_0^2) = G x^\alpha (1-x)^{B-1} \quad (37)$$

where A, C, D, B, G are the parameters of the unpolarized case. In what follows, we shall use $0 \leq \alpha \leq 0.5$, the range proposed by ref. [16] in agreement with [14].

The other ingredients of the formalism, i.e., the probability distributions for each constituent quark, are defined according to the procedure of Traini et al. [7], that is, a constituent quark, $q_{0\pm}$, has a probability distribution determined by

$$q_{0\pm}(z, \mu_0^2) = \frac{1}{(1-x)^2} \int d^3k n_{q_{0\pm}}(|\vec{k}|) \delta\left(\frac{z}{1-z} - \frac{k^+}{M}\right), \quad (38)$$

where $q_{0\pm}$ denotes the q_0 th constituent quark whose spin is aligned (anti-aligned) to the nucleons spin while $n_{q_{0\pm}}(|\vec{k}|)$ is the momentum density distribution for the valence quark momentum \vec{k} and equivalent spin projection. $n_{q_{0\pm}}(|\vec{k}|)$ can be evaluated projecting out the appropriate spin and flavor component of the constituent quark and in the corresponding baryonic state is given by [7]

$$n_{u_0/d_0,\pm} = \langle N, J_z = +\frac{1}{2} | \sum_{i=1}^3 \delta(\vec{k} - \vec{k}_i) \frac{1 \pm \tau_i^z}{2} \frac{1 \pm \sigma_i^z}{2} | N, J_z = +\frac{1}{2} \rangle \quad (39)$$

Eq.(38) includes support correction and satisfies the particle number sum rule [7].

Let us briefly comment about the other leading twist polarized structure function, namely the chiral odd transversity function h_1 . The question we briefly want to address is how the *ACMP* procedure changes our previous conclusions [17]. Kirschner et al. [18] find that the Regge behavior for h_1 is roughly constant and therefore consistent with our choice for the behavior of g_1 , i.e., $\sim x^{0 \div \frac{1}{2}}$ [14]. Note that the Regge behavior is dominant at low x and low Q^2 , where the enhancement due to gluon radiation, given by QCD evolution, is not yet efficient.

The determination of the large x behavior of the structure function as discussed previously for g_1 is dominated by the independence of the softly emitted partons and therefore should be the same for the transversity distributions. These arguments lead us to conjecture that, for non-relativistic models of hadron structure, the *ACMP* mechanism maintains at the hadronic scale the almost equality between these two polarized structure functions,

$$h_1(x, \mu_0^2) = g_1(x, \mu_0^2). \quad (40)$$

Evolution will produce the difference between them as already stated in our previous analysis [17].

3 Results

We will discuss the results of our calculation of the polarized structure function g_1 for the proton and the neutron, evaluating the polarized constituent momentum distributions, Δu_o and Δd_o , within the algebraic model of Bijker, Iachello and Leviatan [19], which proved so succesful in our previous work [9]. The parameters of the wave functions are kept as determined by their authors, which fitted them to static properties of hadrons,

since the present scheme provides us automatically with the momentum sum rule and therefore no ad hoc modification of the model wave functions has been necessary.

To evaluate g_1 at the experimental scale we will perform a NLO evolution of the model parton distributions. It is known that perturbative QCD to this order allows the proposal of varied factorization schemes [20], whereby one is able to define the partonic distributions in different ways without altering the physical observables. In our analysis the parton distributions are determined by the quark model through the ACMP procedure. Which factorization scheme should we apply? It is evident that different factorization schemes lead to different results. We have adopted on physical grounds the AB scheme as defined in ref.[21] ². In it some relevant physical observables, such as $\Delta\Sigma$, are scale independent, i.e., they behave as conserved quantities, and therefore the partons have a well defined interpretation in terms of constituents ³. A detailed analysis of factorization scheme dependence in model calculations of polarized structure functions will be presented elsewhere [24].

Let us initially use our previous parametrization of the $\Delta\Phi$ functions as determined in the unpolarized case, Eqs. (35) – (37), with all the caveats expressed repeatedly [9]. Then we are able to predict the parton distributions at the hadronic scale and therefore their first moments can be calculated, leading to:

$$\begin{aligned}\Delta q_v(\mu_0^2) &= \Delta u_v(\mu_0^2) + \Delta d_v(\mu_0^2) = \\ &= \int dz(\Delta u_0(z, \mu_0^2) + \Delta d_0(z, \mu_0^2)) \int dx \Delta\Phi_{qq_v}(x) \\ &= 0.534 \div 0.662 ,\end{aligned}\tag{41}$$

the first value corresponding to $\alpha = 0.5$ and the second to $\alpha = 0$, being α the Regge intercept;

$$\Delta q_s(\mu_0^2) = \int dz(\Delta u_0(z, \mu_0^2) + \Delta d_0(z, \mu_0^2)) \int dx \Delta\Phi_{qq_s}(x) = 0.0085 \div 0.018,\tag{42}$$

which disagrees not only in magnitude, but also in sign, with the AB data analysis in [16]. In fact one should realize that our calculation contains certain peculiarities since we use the AB evolution scheme in a symmetric sea, a feature which is in the spirit of the ACMP model. The structure of our sea, as reflected in Eqs. (24) and (26) leads to simplifications in the evolution. In particular, the sea does not contribute to a_3 nor a_8 , i.e., under our assumptions the different contributions cancel out. Keeping this in mind, it turns out that $\Delta q_s(\mu_0^2)$ is related to Δs , the first moment of the polarized strange sea, and using for the latter the number obtained in [16] one gets: $\Delta q_s(\mu_0^2) = \frac{1}{2}\Delta s = -0.022 \pm 0.005$, at variance with (42).

²It consists in modifying minimally the NLO polarized anomalous dimensions [22], calculated in the \overline{MS} scheme, in order to have the axial anomaly governing the first moment of g_1 , as proposed in Ref [23].

³It must be pointed out that, if we had used the \overline{MS} scheme, the results would have been in better agreement with the data. However we believe that this accidental agreement hides some physics, as will become clear later on.

We can also predict:

$$\Delta g(\mu_0^2) = \int dz (\Delta u_0(z, \mu_0^2) + \Delta d_0(z, \mu_0^2)) \int dx \Delta \Phi_{qg}(x) = 0.295 \div 0.357, \quad (43)$$

in reasonable agreement with the recent calculation of ref. [25].

Using our assumptions for the sea, Eqs. (24) and (26), we may calculate the following quantities:

$$a_8 = \Delta u_v(\mu_0^2) + \Delta d_v(\mu_0^2) = 0.534 \div 0.662, \quad (44)$$

i.e., the octet charge, whose experimental value is 0.58 ± 0.03 [26], and

$$\Delta \Sigma = 6\Delta q_s(\mu_0^2) + a_8 = 0.584 \div 0.770, \quad (45)$$

which is our prediction for the spin carried by the quarks and the antiquarks. The estimate for this quantity in [16] is 0.45 ± 0.09 .

For the singlet charge we get

$$a_0(\mu_0^2) = \Delta \Sigma - 3 \frac{\alpha_s(\mu_0^2)}{2\pi} \Delta g(\mu_0^2) = 0.511 \div 0.682, \quad (46)$$

and finally, for the isospin charge

$$a_3 = \Delta u - \Delta d = 0.888 \div 1.104, \quad (47)$$

to be compared with $a_3 = 1.257 \pm 0.003$, experimental value as in [27].

In order to compare with the experimental DIS data we perform now the AB evolution. Results are shown in Figs. 1, 2 for the proton and the neutron, respectively. It seems that some physics is missing in the above description as signalled by the disagreement with the neutron data.

Looking at the first moments we realize that specially our determination for the sea looks very poor (cf. Eq.(42) and discussion below.). Can this be the origin of the neutron problem? The fact that our result (42) is inadequate means that our hypothesis (v), based on ref. [15], does not apply to the sea.

Let us choose $\Delta \Phi_{qqs}$ to reproduce the experimental sea data. This implies

$$\Delta \Phi_{qqs}(x, \mu_0^2) = \Delta C_s x^\alpha (1-x)^{D-1} \quad (48)$$

where $\Delta C_s = -0.13 \div -0.06$, which has been chosen so that

$$\Delta q_s(\mu_0^2) = -0.022 \pm 0.005 \quad (49)$$

in agreement with ref. [16].

With this parametrization we also get

$$a_0(\mu_0^2) = 0.330 \div 0.443, \quad (50)$$

and our prediction for the spin carried by the constituents is

$$\Delta \Sigma = 0.402 \div 0.530, \quad (51)$$

being 0.45 ± 0.09 the value given in [16]. Finally, the estimates for $\Delta g(\mu_0^2)$, a_8 , and a_3 do not change and are given by Eqs. (43), (44) and (47).

After evolving, Fig.3 shows that the neutron calculation improves substantially, while the proton one remains quite the same as shown in Fig. 4. It is thus clear that it was too naive to use the unpolarized data to fit the polarized constituent sea structure function.

We have traced back the remaining disagreement with the neutron data to the symmetric treatment of u and d quarks. It can be shown that a weak breaking of the SU(6) symmetry in the quark model used [19] and/or in the constituent quark structure functions improves considerably the agreement [24]. The neutron is extremely sensitive to small changes in the valence structure.

4 Conclusions and Outlook

The present calculation shows that our description of the unpolarized structure functions [9] can be successfully extended to the polarized case. Therefore, low energy models seem to be consistent with DIS data when a structure for the constituent quarks is introduced. We have chosen this structure, following the ACMP description [8], to be consistent with well known phenomenological inputs, such as Regge behavior at low x and counting rules at large x . This assumption made it possible in the unpolarized case to fully define the procedure with only one new parameter, to which the predictions were not very sensitive.

Using a physically motivated minimal prescription for the polarized case, with no additional parameters, we are able to obtain a good prediction of the the proton data [28, 29]. The minimal procedure fails, however, to reproduce the recent accurate neutron data [30]. Relaxing the minimal procedure, with the addition of only **one** new parameter to define the polarized sea, we obtain a significantly improved description also for the neutron data. A perfect agreement would be gotten by introducing an SU(6) breaking mechanism. It is worth emphasizing the importance of the neutron data in disentangling the fine details of the structure.

The outcome of our calculation is not surprising. We had defined the sea by looking at observables, like the unpolarized structure function F_2 [9], which are not very sensitive to scrutinize its distributions. Here, we are analyzing new polarization observables, which depend stronger on the structure of the sea. This new information has motivated a more precise determination of the constituent quark structure functions. For example, it is well known, that the Ellis-Jaffe sum rule for the neutron arises from the vanishing of the polarized sea. This description had to be abandoned when the EMC data first appeared. Showing that a not negligible g_1 for the neutron is consistent with a large contribution from the polarized sea is just rediscovering history in our scheme.

The calculation has also clarified the role of the gluons and the valence quarks. It is clear that the gluons become important through the evolution process, i.e., it is the soft bremsstrahlung gluons which acquire a large portion of the partonic spin. Moreover in the case of the neutron we have realized that the SU(6) symmetric valence quark

contribution basically cancels out and it is the deviation from this symmetry which leads to our remaining discrepancy.

The crucial role played by the sea and isospin breaking effects in the description of the polarized data is demanding an explanation beyond our solution. As mentioned in other occasions, our starting quark model does not implement chiral symmetry breaking, therefore the sea is generated solely at the level of our constituent quark structure functions. Does the procedure thus far developed implement chiral symmetry breaking properly? Data seem to confirm this statement. However, there is an alternative approach, originating also at the very beginning of DIS parton physics [31], which has gained followers after the rebirth of effective theories and we could label under the generic name of chiral procedure. Under this philosophy, the sea would originate also from the mesonic degrees of freedom used to define the chiral quark models. One expects, that the factorization procedure developed in our approach to incorporate the constituent quark structure, could be extended to these models by introducing also the structure functions of the elementary mesons. It has to be investigated if this scheme is able to produce as good descriptions of the data as the present one. If this were the case, there would be a duality of approaches modelling the confinement mechanism. To test these models, until QCD is not solved, experiments should guide the efforts with the aim of predicting new phenomenology.

A comment about the most common factorization schemes is necessary. Had we chosen the \overline{MS} scheme for our calculation, our result would have basically fitted the data. The sea would have been determinant in explaining the data and the other mentioned effects practically inexistent. Taking the AB scheme has led to good, but certainly not perfect, agreement with the data and therefore to the necessity of finding other possible mechanisms to interpret the nucleonic structure. It is important that in sensitive scenarios, like the neutron, one uses a completely consistent procedure.

We would like to stress that within our procedure the *spin problem*, as initially presented, does not arise. The constituent quarks carry all of the polarization. When their structure is unveiled this polarization is split among their different partonic contributions in the manner we have described and which is consistent with the data. The quality of both unpolarized and polarized data thus far analyzed confirm the validity of the approach. We have showed also, that with very reasonable assumptions, the scheme becomes highly predictive, a feature which is necessary for the planning of future experiments.

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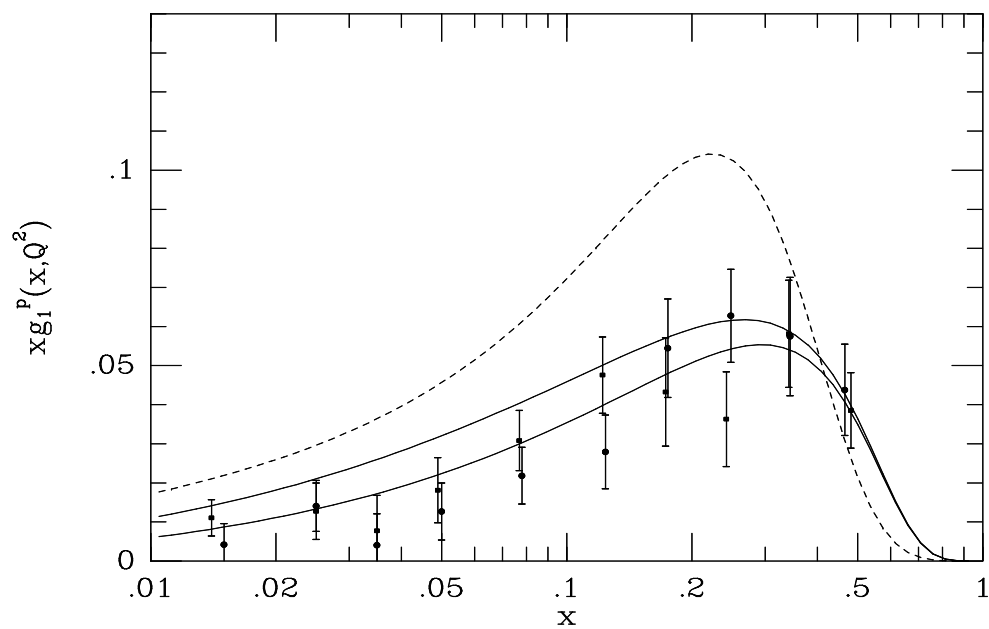
Captions

Figure 1: We show the structure function $xg_1^p(x, Q^2)$ obtained at $Q^2 = 10 \text{ GeV}^2$ by evolving at NLO the model calculation [19] without considering the structure of the constituents [7] (dashed). The same quantity, $xg_1^p(x, Q^2)$, evolved at NLO to $Q^2 = 10 \text{ GeV}^2$, for the two extreme Regge behaviors mentioned in the text, is given by the two full curves ($\alpha = 0$ is the upper curve, here and also in the following figures). The parameters used are those of our calculation for the unpolarized case [9]. The data from refs. [28, 29] at $Q^2 \approx 10 \text{ GeV}^2$ are also shown.

Figure 2: The structure function $xg_1^n(x, Q^2)$ for the neutron evolved at NLO to $Q^2 = 5 \text{ GeV}^2$, for the two extreme Regge behaviors mentioned in the text, is shown by the two full curves. The parameters used are those of our calculation for the unpolarized case [9]. The data from refs. [30] at $Q^2 = 5 \text{ GeV}^2$ are also shown.

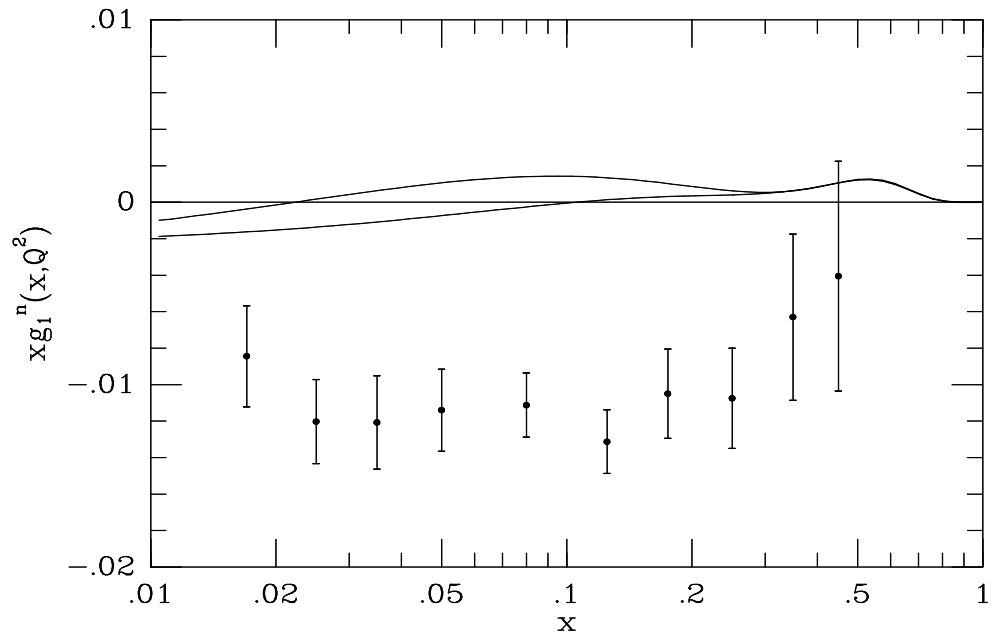
Figure 3: The structure function $xg_1^n(x, Q^2)$ for the neutron evolved at NLO to $Q^2 = 5 \text{ GeV}^2$, for the two extreme Regge behaviors mentioned in the text, is shown by the two full curves. The new parametrization of the sea, Eq. (48), is used. The data from refs. [30] at $Q^2 = 5 \text{ GeV}^2$ are also shown.

Figure 4: The structure function $xg_1^p(x, Q^2)$ for the proton evolved at NLO to $Q^2 = 10 \text{ GeV}^2$, for the two extreme Regge behaviors mentioned in the text, is given by the two full curves. The new parametrization of the sea, Eq. (48), is used. The data from refs. [28, 29] at $Q^2 \approx 10 \text{ GeV}^2$ are also shown.



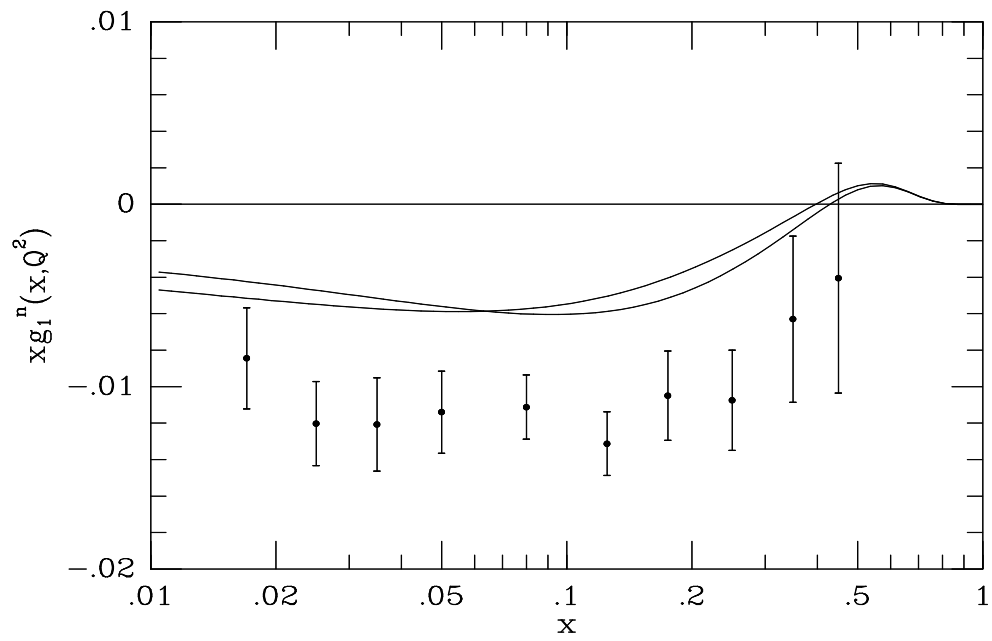
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FIGURE 1



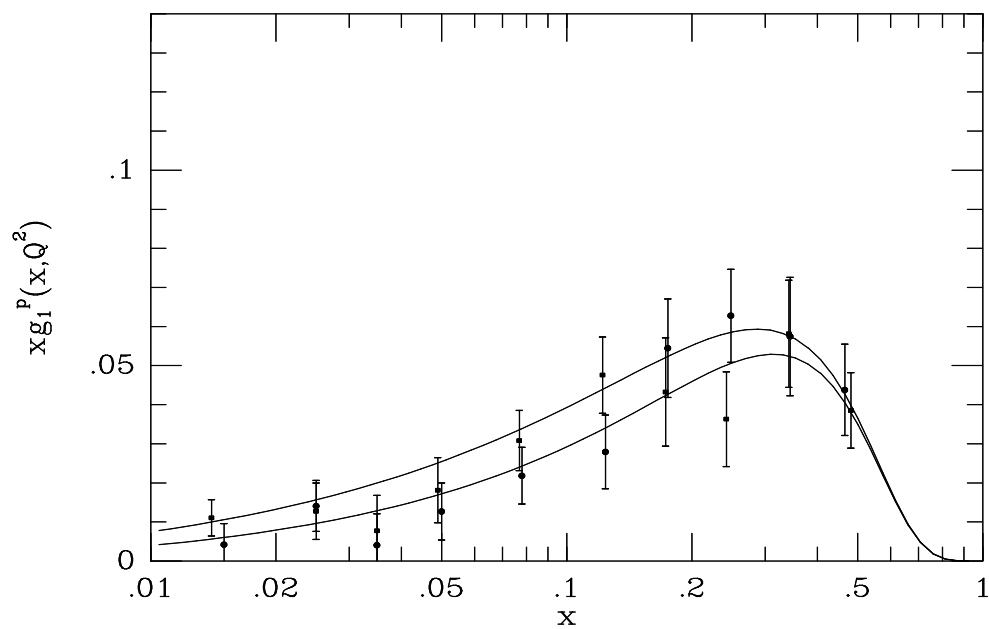
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FIGURE 2



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FIGURE 3



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FIGURE 4